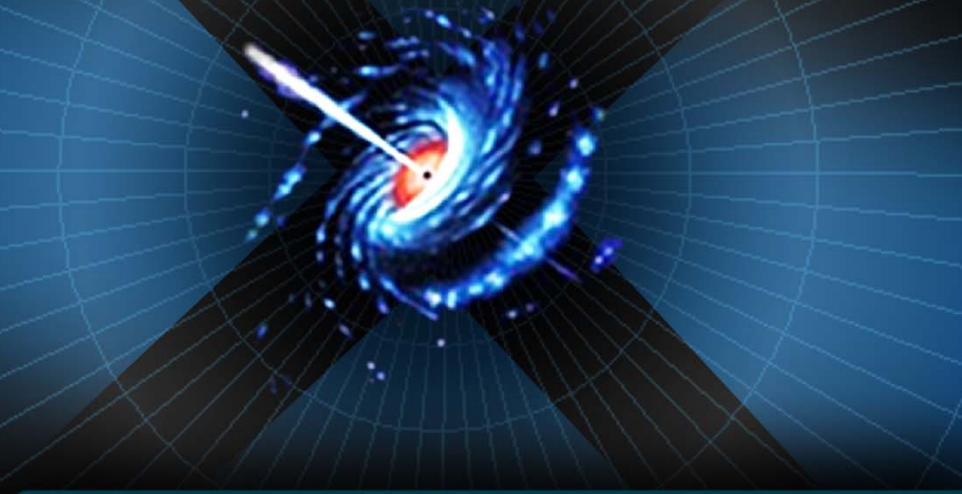
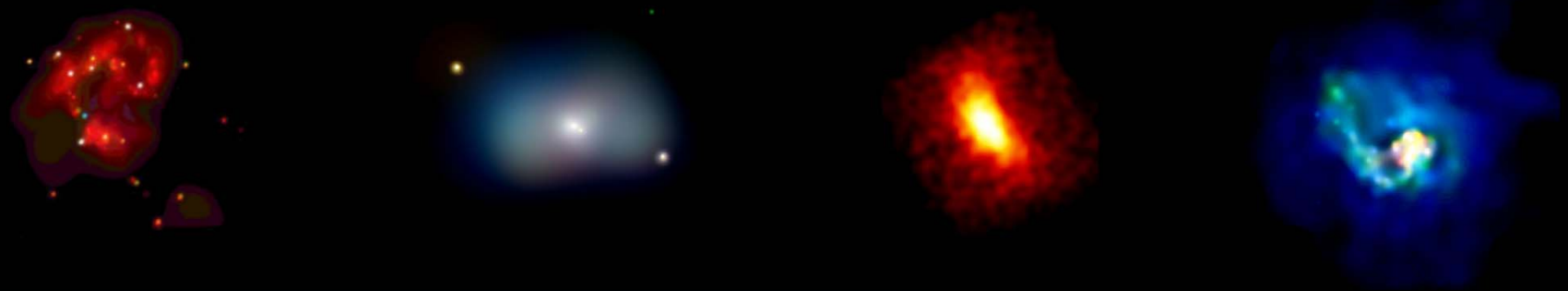
Facility Science Team Meeting (FST)
Cambridge, MA / February 15 & 16, 2006

Constellation-X

The Constellation X-ray Mission



Project Overview Configuration



Jean Grady/NASA GSFC

Topics

- **Project Overview - Jean Grady**
  - Summary of Progress and Events
  - Configuration Summary
  - Technology Assessment
  - Technology Progress Summary
  - Technology NRA
  - Budgets
  - Wrap-up

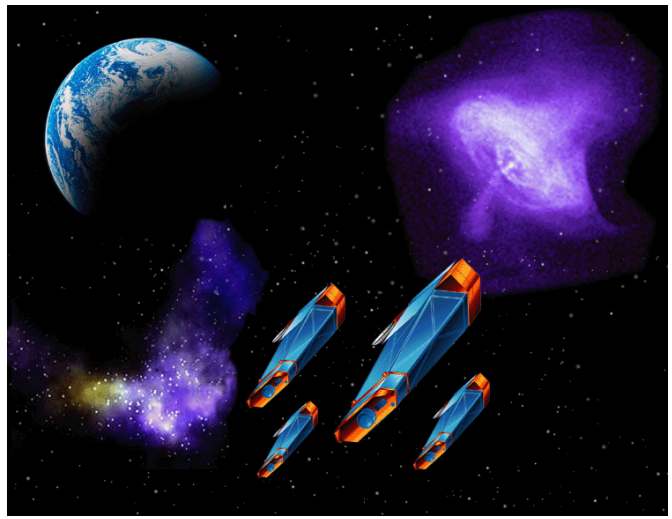
- **Single Launch Configuration Studies**
  - Trades - Mark Freeman/SAO
  - Details of single launch with 4 SXTs - Gabe Karpati/GSFC

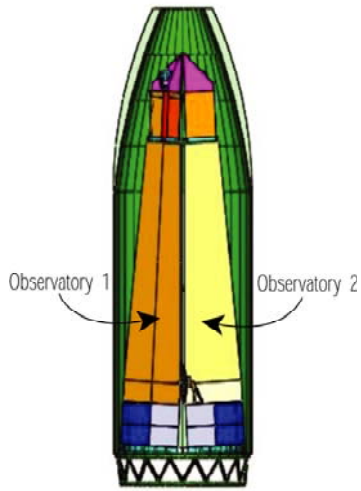
Summary of Progress and Events Since Last FST Meeting (Oct. 2004)

- **Exploration of Collaboration with ESA/XEUS (Nov 2004 to July 2005)**
  - Collaborative Formation Flying study in NASA GSFC Integrated Mission Design Center (Dec 2004)
  - Con-X/XEUS Collaborative Science Meeting (Feb 2005)
  - Follow-up studies geared toward accommodating reflection gratings, formation flying analyses
  - Ended collaborative studies (July 2005)
- **Single Launch Configuration Development (July 2005 to Feb. 2006)**
  - Trades of configurations with range of focal lengths (July to Oct 2005)
  - Concept development of "10-4" configuration (Nov 2005 to Feb 2006)
- **Technology Assessment (Nov 2005 to Jan 2006)**
  - Commissioned by Ed Weiler; Conducted by GSFC Applied Engineering & Technology Directorate
  - Initiated in November 2005 (both Con-X and LISA)
  - Report completed January 2006

Reminder of 4 Satellite "Reference" Configuration

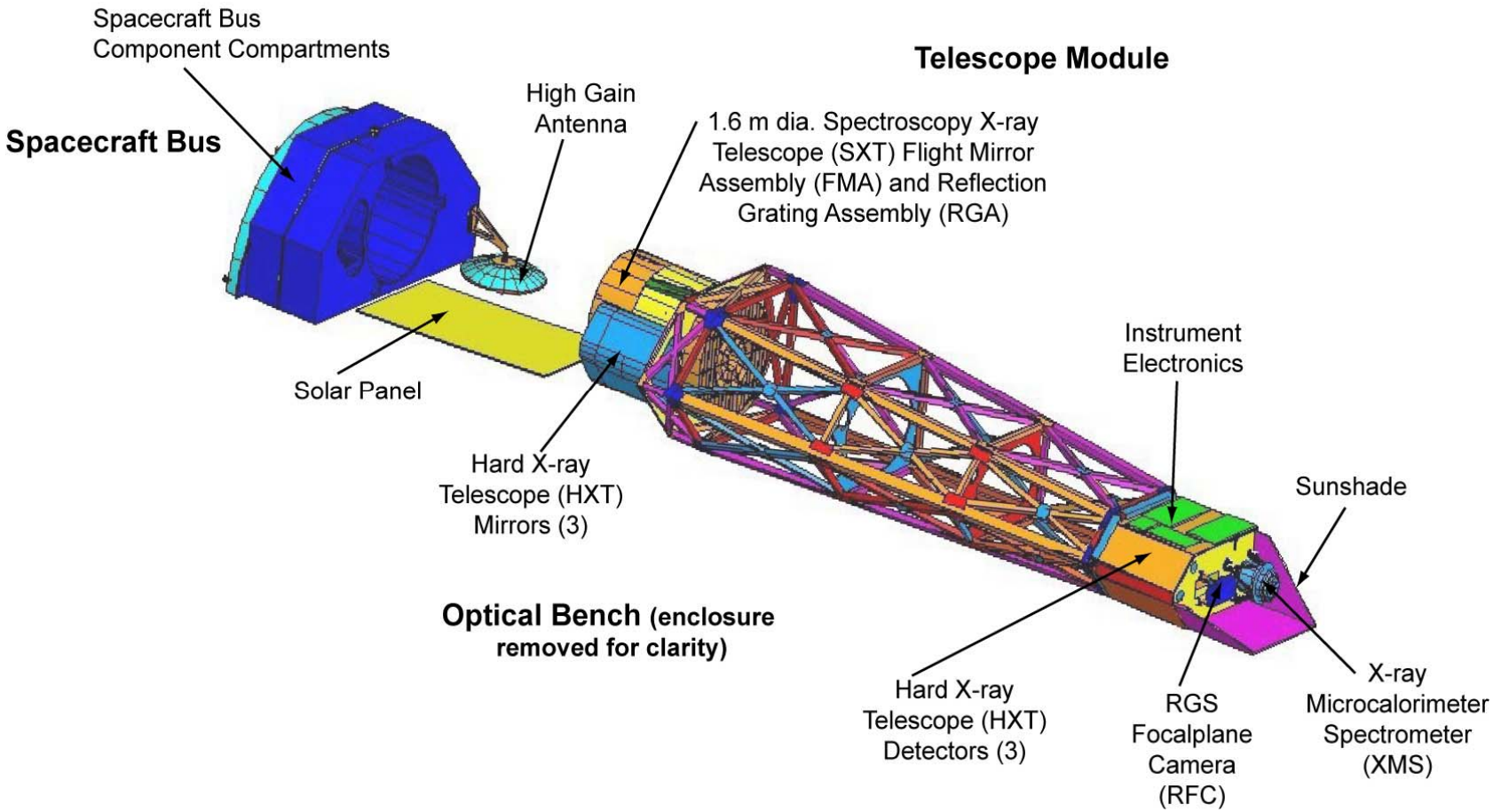
- 4 identical satellites
  - Each with portion of the mission collecting area
  - Simultaneously, independently view same target (no formation flying)
- Launch two at a time on Atlas V-5 class vehicles
- L2 orbit provides increased observing efficiency, thermal stability
- Focal length is 10m
- Each satellite payload consists of:
  - One (1) Spectroscopy X-ray Telescope (SXT) Flight Mirror Assembly, 1.6m dia shared by
    - One(1) Reflection Grating Spectrometer (RGS)
      - » Reflection Grating Assembly (RGA) mounts in SXT Flight Mirror Assembly
      - » RGS Focalplane Camera (RFC)
    - One (1) X-ray Microcalorimeter Spectrometers (XMS)
  - Three (3) Hard X-ray Telescope mirror/detectors systems





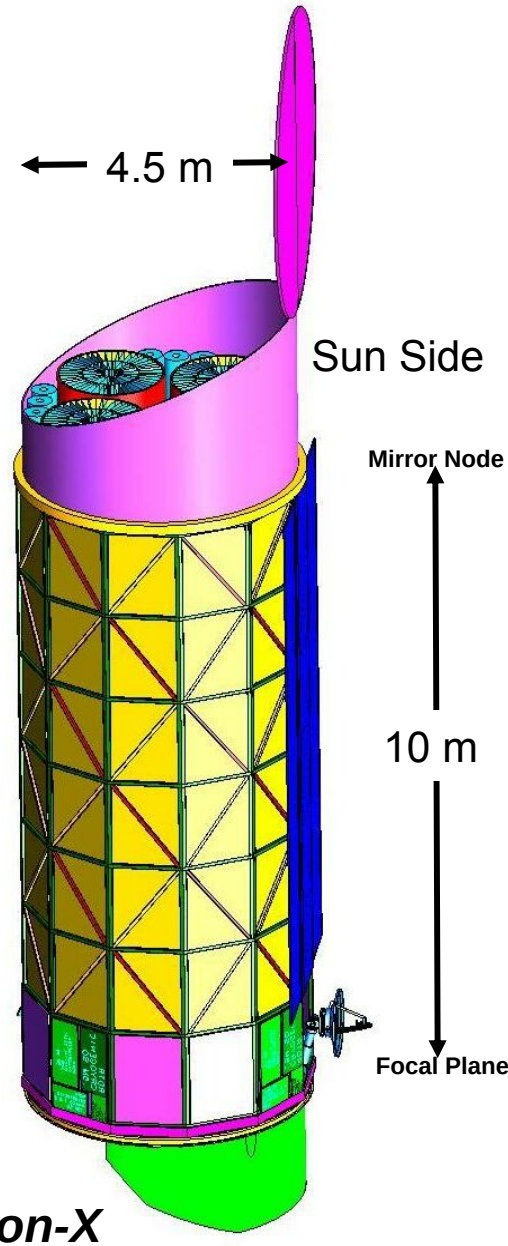
Reference Launch w/ 2 Satellites on Atlas V class vehicle

Reminder of 4 Satellite "Reference" Configuration — cont. ("Expanded" view, one of four satellites shown)



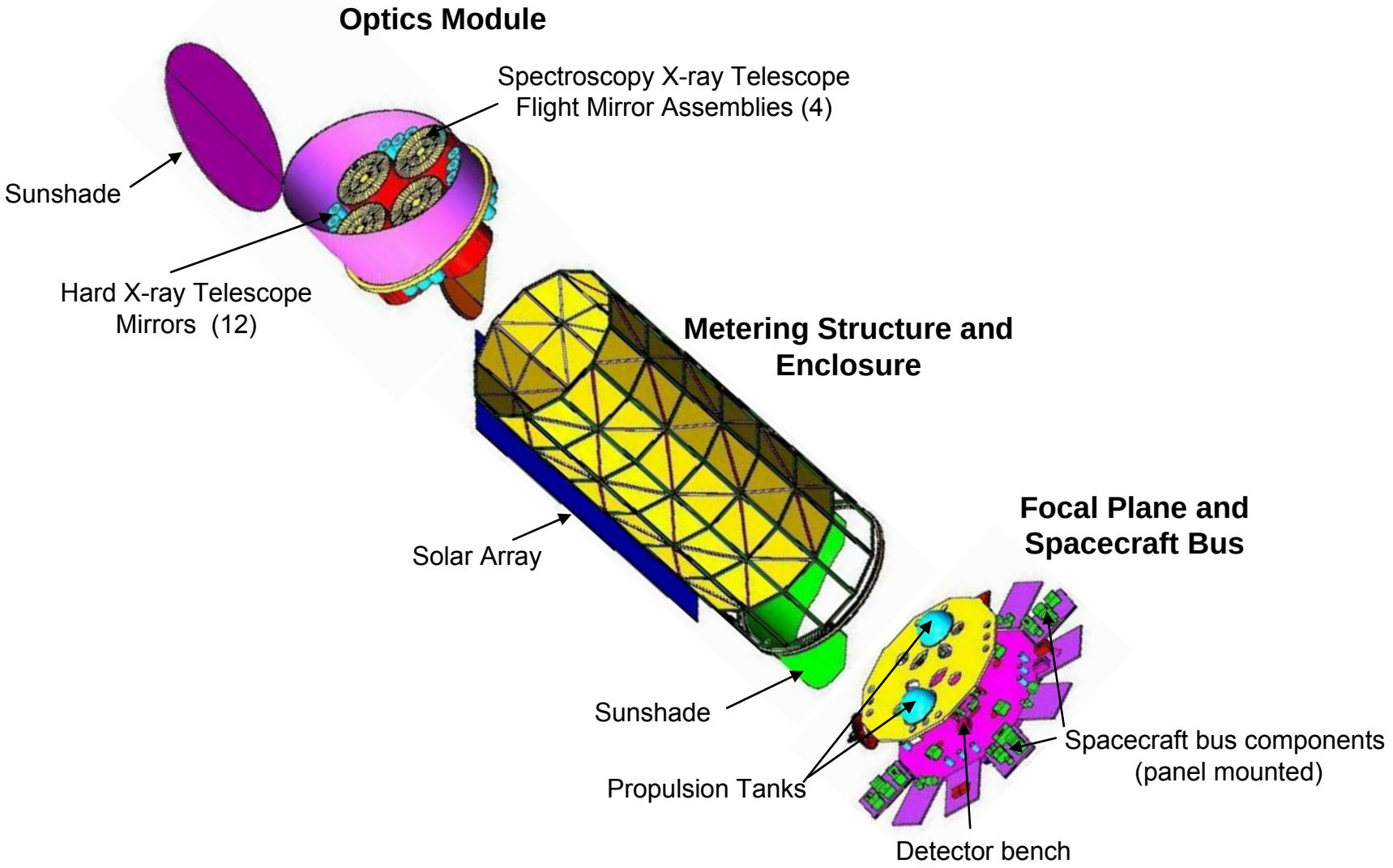
Single Launch Observatory Configuration "10-4"

- Single satellite on single launch vehicle (Delta IV H) meets Constellation-X performance requirements
- Orbit remains at L2
- Mirrors and Instruments same as for 4 satellite "Reference" configuration
  - Same focal length of 10 m
  - Same size and number of mirrors and instruments
  - Same technology required and same technology development roadmaps
- Full Mirror and Instrument Payload
  - 4 Spectroscopy X-ray Telescope (SXT) Flight Mirror Assemblies, 1.6m dia each
  - 4 Reflection Grating Spectrometers
  - 4 X-ray Microcalorimeter Spectrometers (XMS's)
  - 12 Hard X-ray Telescope mirror/detectors systems
- Spacecraft bus and Observatory System
  - Spacecraft components generally off-the-shelf
  - Overall mass margin reasonable for this stage in the program



Configuration is shaping up to be the new "Reference" for Con-X

Single Launch Mission Configuration ("Expanded" view shown for clarity)



Technology Assessment

- **Assessment was GSFC internal review of both LISA and Con-X technologies**
- **Charter included:**
  - **Confirm that all required technologies have been identified and are under development**
  - **Assess and validate the current technology status, utilizing Technology Readiness Levels (TRL)**
  - **Assess and validate the feasibility of the technology maturation plans and technical criteria for development through TRL 6**
  - **Identify weaknesses, risks, etc**
- **Report completed January 20, 2006**
  - **Significant progress since TRIP (2003) was noted**
  - **Technology requirements found to be understood; plans for completing development sound**
  - **"Con-X has the distinct advantage in that they do not really need a flight experiment to qualify their technology."**

Con-X Technology Assessment Summary

*Critical Technology**	*TRL Prime*	*TRL Alternate*
Spectroscopy X-ray Telescope Mirror	3-4	
Reflection Grating Spectrometer Gratings	3-4	
Reflection Grating Spectrometer CCD Detector	3	
Microcalorimeter	4	4
Adiabatic Demagnetization Refrigerator	4	3
Cryocooler	4-5	4, 4
HXT mirrors	4-5	4
HXT focal plane system	5	

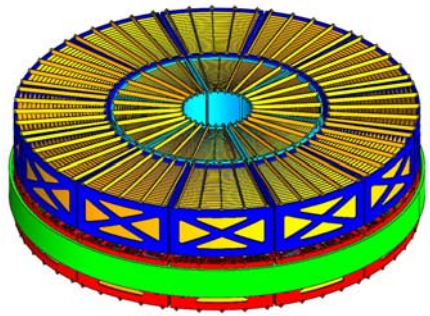
***Remaining observatory system and subsystem technologies including spacecraft bus are considered at TRL 6 or higher.**

***Many thanks to all those who contributed to the Technology Assessment*!**

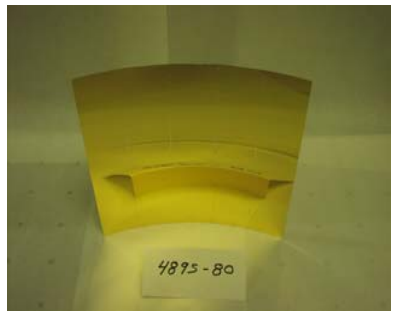
TECHNOLOGY STATUS: Large, Lightweight X-ray Mirrors for Spectroscopy X-ray Telescope (SXT)

- Segmented, modular lightweight mirrors flight-proven on ASTRO-E and previous missions
- Glass Mirror Segments
  - Produced mirror segments that meet flight performance specification (with and without epoxy replication)
  - Consistently forming mirror substrates that are of quality to meet flight angular resolution requirements with epoxy replication
  - Successful vibration test of mirror segments
- Alignment Tools and Techniques in development
  - X-ray test of alignment pathfinder planned for spring 2006

ASTRO-E mirror

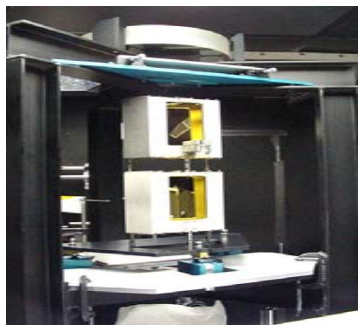


Con-X mirror design concept



Glass mirror segment

Substrate forming in oven

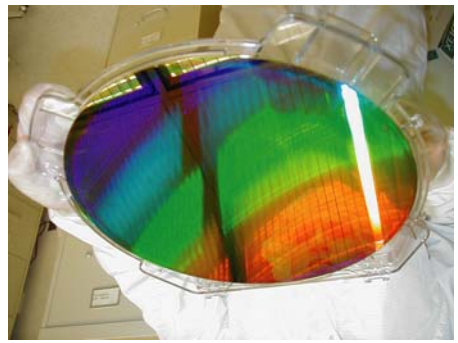


Mirror segment alignment pathfinder

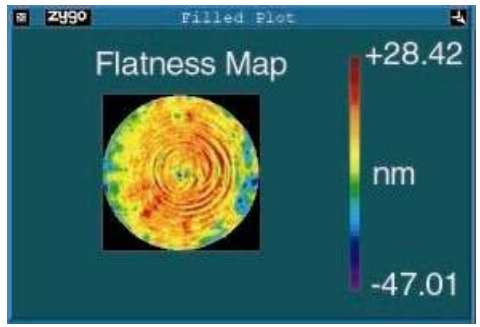
TECHNOLOGY STATUS: Gratings and CCD's

Grating

- **Grating Patterning – Scanning Beam Interference Lithograph – SBIL (MIT)**
  - Patterned gratings in required size
  - Demonstrated required blaze and smoothness; required line density
  - Currently upgrading SBIL to accommodate radial (fan-shaped) grooves (to be complete '06)
- **Grating Patterning – Holographic (Jobin Yvon, U of Colorado)**
  - Ruled high line density radial grating
- **Demonstrated substrate flatness better than required (MIT)**
- **Prototype masters and replicas show record-level efficiencies in X-ray test (MIT)**

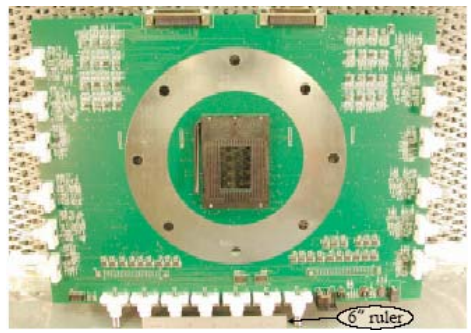


SBIL patterned grating (MIT)



CCD (MIT/LL)

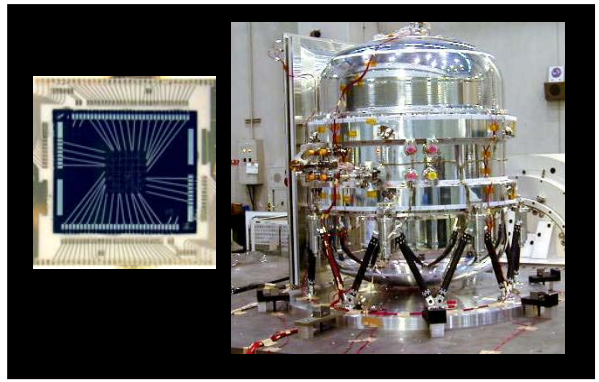
- **High-speed readout Event Driven CCD**
  - Successfully completed two lot's of Event Driven CCD's
- **High quantum efficiency, high production yield**
  - Demonstrated high yield "chemisorption" backside processing (U of Arizona on LL devices)
  - Recent progress on LL Molecular Beam Epitaxy backside processing also looks promising



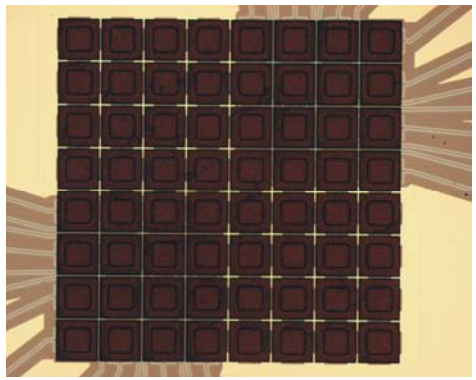
EDCCD: Large motherboard and camera plate (MIT)

TECHNOLOGY STATUS: Microcalorimeters and Coolers

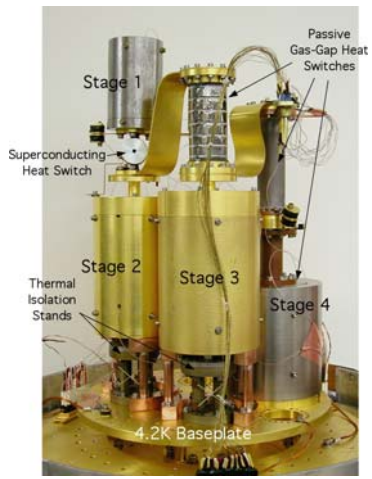
- Suzaku/XRS provides flight heritage
- Transition Edge Sensor – TES (GSFC, NIST)
  - Demonstrated energy resolution required for Con-X at 1.5 keV and 6 keV
  - Routinely fabricating 8x8 arrays with high quantum efficiency, high fill factor
  - Successfully multiplexed 16-channels
- Continuous Adiabatic Demagnetization Refrigerator – CADR (GSFC)
  - 4-stage breadboard CADR demonstrating required operating and heat rejection temperatures and cooling power
- Mechanical Cryocooler
  - Under development for JWST; meets Con-X requirements



XRS



8X8 array with Bi/Cu absorbers

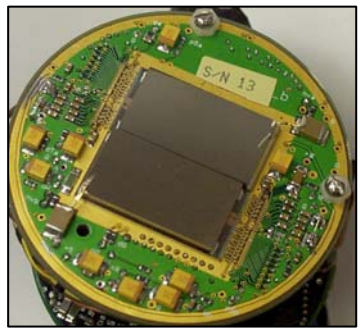


4-stage CADR

TECHNOLOGY STATUS: Hard X-ray Telescope (HXT)

- **Glass Mirrors (Columbia, CalTech, DSRI)**
  - HEFT (balloon) mirror meeting Con-X mass and performance requirements has successfully flown
  - Prototype mirrors have performances better than required; have been successfully acoustic and vibration tested
- **Nickel Mirrors (SAO, MSFC, Brera)**
  - Single shell mounted prototype has demonstrated angular resolution better than required in X-ray test
  - Fully lightweighted shells have been produced
- **Detectors (CalTech)**
  - CdZnTe hybrid pixel detectors have been demonstrated on HEFT
    - Meets required performance
    - Vibration tested

Prototype mirror acoustics tested at JPL facility



CdZnTe hybrid pixel detector

HEFT 72-shell glass mirror optic

Single shell nickel mirror in X-ray test at PANTER

CdZnTe vibration test

Technology NRA Originally Planned for Release in Spring FY06

- Project is in the process of developing a solicitation (through ROSES NRA) for Con-X instrument technology development program
  - Last technology competition held in 1998
- Focuses on technology for Con-X instruments:
  - Reflection Grating Spectrometer
  - X-ray Microcalorimeter Spectrometer
  - Hard X-ray Telescope
- Goal is to advance technology in the TRL 3-6 range, bring in new ideas for technology, and is essential to prepare and sustain teams for instrument AO in future
- NRA release date TBD (pending budget allocation)

Instrument Technology Integrated Product Team's (IPT's) Dissolved; Instrument Scientists Appointed

- In anticipation of the technology NRA and to encourage open and fair communication between the Project and all Con-X technology providers, Technology IPT's have been dissolved
- Instrument Scientists have been appointed:
  - Jean Cottom for the Reflection Grating Spectrometer (RGS)
  - Rick Shaffer for the X-ray Microcalorimeter Spectrometer (XMS)
  - Ann Parsons for the Hard X-ray Telescope (HXT)
- Instrument Scientists are GSFC civil servant; duties include
  - Assure science requirements are addressed by technology development efforts
  - Provide a key interface between the instrument technology developers and the mission level studies
  - Assist in generation of specifications and statements of work for future technology and instrument solicitations
- Instrument Scientists are ineligible to propose for or receive funding for Con-X technology development

Many thanks to former-IPT Leads Kathy Flanagan, Rich Kelley and Fiona Harrison for their dedication and service!

Summary

- **Con-X Single Launch mission configuration is robust and cost-effective**
- **Technology Assessment confirms good progress on technologies; solid maturation plans**
- **NRA for selecting instrument technologies to fund is still in the plan; release date pending budget allocations**